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Night Vision Goggle Field-Expedient Visual Acuity Adjustment Procedures: Initial Experiment

Jean L. Dyer, Keith M. Young, Scott A. Watson, and Nancy R. McClure
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14. ABSTRACT *(Maximum 200 words)*:

The third-generation image intensification technology in night vision goggles (NVGs) used by ground forces provides, at best, 20/40 or 20/45 visual acuity. These acuity levels cannot be achieved unless soldiers adjust their NVGs properly. Documentation available to soldiers does not address optimum adjustment techniques developed by the aviation community nor does it address what can be used in the field to achieve a good setting.

We examined the effectiveness and utility of 15 different objects commonly available to soldiers to determine which provided the best visual acuity readings with the AN/PVS-7B NVGs. After training and practice, acuity improved by 25% over the baseline assessment. No large differences in readings occurred among the objects. However, a more definitive picture emerged when the average readings were combined with measures of variability and soldier preferences. The initial recommendation is to use one of the following objects for NVG adjustment: tree trunk, vehicle, vehicle trail, stars, blue chem light, or an infrared chem light. Not recommended are bright and/or red light sources, white paper, and trees silhouetted against the night sky. Problems in assessing acuity with NVGs are also discussed.

15. SUBJECT TERMS

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Night Vision Goggle Field-Expedient Visual Acuity Adjustment Procedures: Initial Experiment

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FOREWORD

Fighting at night has become increasingly important to combat success as new and better generations of night equipment allow soldiers to see and operate more effectively. The goal of the NIGHTFIGHTER program being executed by the Infantry Forces Research Unit (IFRU) of the U.S. Army Research Institute for the Behavioral and Social Sciences is to improve soldier, leader, and unit training for night operations. Research under NIGHTFIGHTER encompasses a broad spectrum of skills and issues, ranging from basic skills which do not require special equipment to the specialized skills demanded by the most sophisticated night technologies, and from training issues which have persisted over time to those emerging as night operations become more common.

The research reported here is on techniques which enable soldiers to maximize their visual acuity with night vision goggles. Night vision goggles are key to seeing at night, but optimum use does not occur unless the goggles are adjusted properly. Field-expedient techniques which provided the best acuity and were of the greatest utility were identified. The procedures addressed omissions in the current night vision goggle technical manuals.

Research findings have been given to the Dismounted Battle Space Battle Lab for incorporation in their exportable training package; to the 82d Airborne Division, which participated in the night vision goggle experiments; and to representatives from other Forces Command units. The findings have also been given to the U.S. Army Safety Center in support of their efforts to reduce accidents at night.

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NIGHT VISION GOGGLE FIELD-EXPEDIENT VISUAL ACUITY ADJUSTMENT PROCEDURES: INITIAL EXPERIMENT

EXECUTIVE SUMMARY

Research Requirement:

Night vision goggles (NVGs) greatly improve the ability of soldiers to conduct night operations such as moving, shooting, and driving. Although the visual acuity through NVGs is not 20/20, it is much greater than that achieved with unaided night vision. However, the NVGs must be adjusted properly to achieve maximum visual acuity. Information in the current NVG technical manuals do not provide this material nor address techniques effective in field situations. The research examined the effectiveness and utility of various field-expedient objects for focusing NVGs, as well as the impact of instruction and training on adjustment procedures on NVG acuity readings.

Procedure:

On the first night, baseline NVG visual acuity measurements were taken, instruction and training on NVG adjustment procedures were given, and a follow-up reassessment of the baseline measurement was conducted. On the second night, soldiers adjusted their NVGs using 15 field-expedient objects to determine which provided the best acuity. This was a counterbalanced, repeated measures design. Both light and nonlight objects were used. On the third night, soldiers' NVG visual acuity with the six objects that produced the best acuity was reexamined, and soldiers were interviewed on their preferences for the field-expedient objects. Fifteen soldiers participated in the research.

Findings:

After training and practice, visual acuity improved by 25% over the baseline assessment. No large differences in visual acuity readings occurred among the objects. However, when the average readings were combined with measures of variability and soldier preferences, a more definitive picture emerged. The best objects in terms of visual acuity readings, ease of adjustment, and usability in the field were a tree trunk viewed from 10 feet, a vehicle, a vehicle trail that presented a good contrast against its surroundings, stars, a blue chem light, and an infrared chem light. Objects found to be unsatisfactory were bright and/or red light sources, a piece of white paper, and a tree silhouetted against the night sky.

Utilization of Findings:

The correct sequence of steps to use in adjusting goggles as well as the best field-expedient objects for making diopter adjustments should be added to the current NVG technical manuals. It is critical that soldiers maximize their acuity to enhance performance on the battlefield at night as well as increase their safety. The research should be replicated under different ambient light conditions with other soldier populations and with a modified NVG test set to enable more precise predictions regarding the visual acuity readings in typical field settings.

NIGHT VISION GOGGLE FIELD-EXPEDIENT VISUAL ACUITY ADJUSTMENT PROCEDURES: INITIAL EXPERIMENT

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NIGHT VISION GOGGLE FIELD-EXPEDIENT VISUAL ACUITY ADJUSTMENT PROCEDURES: INITIAL EXPERIMENT

Introduction

Night vision goggles (NVGs) greatly improve the ability of the military to conduct night operations. The image intensification technology used in NVGs amplifies portions of the electromagnetic spectrum, enabling soldiers to see and function under conditions that would ordinarily be too dark to operate effectively with unaided night vision.

When new military equipment is fielded, continual use by soldiers is necessary to identify how to maximize employment of the equipment on the battlefield, to determine the most effective means of training, and to identify weaknesses which require correction through training or equipment modification. Clearly NVGs enhance the soldier's ability to see at night. Early tests of NVGs (Anton, 1988; Soechting & Kennedy, 1987; U.S. Army Human Engineering Laboratory, 1975; U.S. Army Infantry Board, 1984), however, showed some problems such as discomfort from the head harness, limited depth perception, restricted field of view, and eye strain. In these initial tests, no attention was paid to training soldiers how to maximize the visual acuity of their goggles. Recently, however, the aviation community has directed its attention to ensuring pilots adjust their goggles for maximum visual acuity before flight (DeVilbiss & Antonio, 1994; DeVilbiss, Antonio, & Fiedler, 1994). Unfortunately, these techniques employ NVG test sets or special visual charts, which are not feasible for field use by ground soldiers. Test sets weigh too much. Visual acuity charts require a controlled light source.

The purpose of the research reported here was to examine the effectiveness and utility of different field-expedient procedures for adjusting the visual acuity of NVGs, specifically the AN/PVS-7A and 7B models used by ground forces, and to make initial recommendations regarding field-expedient techniques. The research was conducted by the Infantry Forces Research Unit of the Army Research Institute (ARI) at Fort Benning, Georgia as part of its NIGHTFIGHTER research program.

NVG Capabilities

Neither second- nor third-generation NVGs provide a Snellen visual acuity of 20/20. With second-generation image intensification technology, such as that in the AN/PVS-5 NVGs, 20/50 is typically cited as the best visual acuity available (Brickner, 1989; Miller & Tredici, 1992). For third-generation technology, used in the most current AN/PVS-7A and 7B NVGs and the aviator's night vision imaging system (ANVIS), 20/40 is typically cited as the best visual acuity attainable. The best acuity levels are usually achievable only indoors under optimal conditions. Under the typical ambient illumination in the field, visual acuity can be decreased substantially.

The importance of adjusting NVGs to maximize the user's visual acuity and performance at night should be obvious. Dyer, Smith, and McClure (1995) demonstrated the effects of visual acuity on night marksmanship, where NVGs were used in conjunction with the AN/PAQ-4A and

4B aiming lights. The effects of good (20/35 to 20/50) and poor (20/60 and 20/70) visual acuity settings with the AN/PVS-7B NVGs were examined. Soldiers adjusted their goggles to the desired visual acuity setting using the Air Force's NVG visual acuity resolution chart (DeVilbiss & Antonio, 1994; DeVilbiss, Antonio, & Fiedler, 1994) on the firing range without controlled illumination. With the poor NVG setting, shot group sizes during aiming light zeroing at 25 m were 1.3 times larger than those achieved by firers with the good acuity setting. Hit probability at range was higher with the good setting, particularly at 75 m (.75 for good acuity, .47 for poor acuity).

NVG Adjustment Procedures

Limited information on how to adjust NVGs properly is available in the AN/PVS-7 technical manuals used by ground forces. To maximize the visual capabilities of the NVGs, the user must make the appropriate eye relief, eye span, focus distance, and diopter adjustments, and perform these adjustments in the proper order.

The technical manual (TM) for the AN/PVS-7A goggles (Department of the Army [DA], 1987) simply states that the user must adjust the eye relief and eye span distance for comfortable use, adjust the objective focus ring for the sharpest view, and turn the eyepiece focus rings for the sharpest view. Guidance in the TMs for the AN/PVS-7B goggles (DA, 1988; 1994) is more detailed and is summarized in Table 1. Although much information is the same in both TMs, the two sequences differ.

Table 1
AN/PVS-7B NVG Adjustment Procedures in the Technical Manuals

Step	1988 TM	1994 TM
1	Adjust **IPD**[a] (eye span). Slide eyepieces together or apart so eye observes entire field at same time.	Set **eye relief** so eyecups seal around the eyes.
2	Adjust **eye relief** for full view of screen.	Adjust **IPD.** Same as step 1, 1988 TM.
3	Adjust **diopter rings**. Close left eye and adjust right ring for clearest focus on image tube screen. Repeat with other eye. Adjust so bright clear image appears.	Adjust **head mount** to align NVGs with eyes. Same as Step 5, 1988 TM.
4	Adjust **objective lens focus** while observing a random object; until sharpest image occurs.	Adjust **diopter rings**. Same as Step 3, 1988 TM, but use the eyecup to obstruct view rather than closing the eye.
5	Readjust **head mount** to align NVGs with eyes.	Adjust **eye relief** to get full view of image.
6		**Readjust diopter rings** for best image.
7		Adjust **objective lens focus** until sharpest image occurs.

[a] IPD stands for interpupillary distance.

The TMs also state that the sharpest image will be observed only when the objective focus lens and both eyepieces are properly focused. The objective focus lens is used to focus on objects at varying distances. The diopter rings correct for refractive errors in each eye. Diopter ring and objective lens adjustments must be made separately. The 1988 TM specifies that eye glasses are not required and should not be used with the goggles. The 1994 TM also states that any readjustment of the eye relief requires readjustment of the diopter rings.

Critical information in the Air Force procedures is omitted in both TMs. What type of objects should be examined when adjusting the diopter rings and the distance of these objects from the soldier are not mentioned. In fact, the 1988 TM states that a "random" object should be used. The TMs do not provide any guidance on the direction in which the diopter rings should be rotated. Interestingly, the TM for the older AN/PVS-5/5A/5B/5C goggles did (DA, 1988, April), specifying that the focus knobs should be turned fully counterclockwise initially. Air Force procedures state to turn the diopter ring fully counterclockwise and then back clockwise just until the image is sharp. A visual acuity chart or a test set is used when making these adjustments. These procedures are described in greater detail below. Both TMs do, however, specify that the diopter adjustments should be made separately for each eye.

Statements in the TMs that prescription glasses are not required and should not be used are misleading. In fact, the diopter range is from +2 to -6, and NVGs do not correct for astigmatism. Therefore, soldiers with certain acuity profiles will benefit from wearing the NVGs with their prescription glasses.

The Air Force procedures also specify a different sequence of steps than the TMs. Diopter adjustments are made only after adjusting the IPD, eye relief, and initial focus for distance. Thus the soldier or aviator first aligns the NVG eyepieces perfectly with the eyes, by performing the eye relief and IPD adjustments. Next, the initial focus adjustment for distance to the object being viewed is made. Then the diopter rings are adjusted. In contrast, both AN/PVS-7B TMs specify adjusting the diopter rings prior to having optimized at least one of these three adjustments. The Air Force then recommends that the diopter and distance focus adjustments be repeated, if necessary, to verify that the sharpest image has been obtained.

The current Soldier Training Publication for all Infantry military occupational specialties (MOS) (DA, 1988, September) includes only the older AN/PVS-5 NVGs, not the more recently-fielded AN/PVS-7A and 7B goggles. The only guidance relevant to setting the visual acuity of the AN/PVS-5 goggles is a reference to adjust the focus ring for each eye separately for the clearest image.

In summary, the guidance available to ground forces regarding the AN/PVS-7 NVGs seems to discount the importance of ensuring that diopter adjustments result in the best visual acuity. The sequence of steps is such that diopter adjustments are made inefficiently and/or prior to adjusting the other required NVG components. In addition, instruction on how to physically rotate the diopter rings and on what objects will result in the best visual acuity is almost nonexistent. Collectively, these factors mean that many ground soldiers will not see as well as they should with their NVGs.

The Air Force systematically documented NVG adjustment and assessment procedures for the different NVG models worn by their pilots (Antonio, 1993; Antonio & Berkley, 1993; Antonio, Joralmon, Fiedler, & Berkley, 1994). These procedures use a NVG resolution chart (42 cm square) in a 20 ft (6.1 m) light-tight test lane. The chart is lit with a lamp equipped with a standard 7W bulb, and so designed to allow only enough luminance to be emitted to represent quarter-moon illumination. The diopter adjustments are made with the NVG resolution chart, which is placed exactly 20 ft (6.1 m) from the aviator. The lamp is placed 10 ft (3.05 m) from the chart.

The NVG resolution chart (Figure 1) presents nine square-wave gratings in a three-by-three format (DeVilbiss, Antonio, & Fiedler, 1994). Each grating pattern is equivalent to Snellen acuity levels between 20/35 and 20/100, specifically, 20/35, 20/40, 20/45, 20/50, 20/60, 20/70, 20/80, 20/90 and 20/100. Each grating pattern is four in. by four in. in size with a 95% contrast. NVG performance is determined by the grating patterns the NVG user can resolve. By rotating the chart, the direction (either horizontal or vertical) of the gratings is changed. This permits four different presentations of the chart, and therefore, four measures of acuity. The overall acuity reading is that associated with the smallest grating correctly identified in at least 75% of the presentations. While observing the chart, the user must make separate diopter adjustments for each eye. The other eye is closed. For each eye, the diopter ring should be turned fully counterclockwise first, and then back clockwise until the lines in the chart are sharp. The diopter ring should not be turned beyond the point at which the lines first become sharply focused. The system's visual acuity is then assessed with both eyes open.

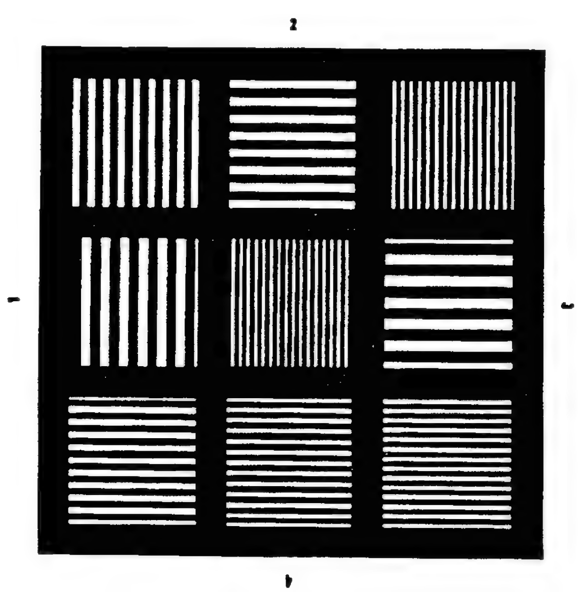

Figure 1. NVG resolution chart.

Within the Air Force, the NVG resolution chart may soon be replaced by a NVG test set such as that described in the Method section of this report. However, the NVG adjustment procedures, that is, the manipulation of the NVG controls to adjust the eye relief, eye span, focus for distance, and diopter setting, do not change when a test set is used. The procedures taught to soldiers in this research were based on the Air Force's procedures.

NVG Adjustment Training and Experience

DeVilbiss, Antonio, and Fielder (1994) compared NVG visual acuity levels obtained with different adjustment procedures. Aviators focused their NVGs with either their "usual" adjustment method, with their "usual" method augmented by the NVG resolution chart, or with the NVG resolution chart following completion of a NVG adjustment procedures class. Data were collected in a NVG test lane. The poorest Snellen acuity with the NVGs (M = 20/52.2) was obtained when aviators used their "usual" method. When the "usual" method was supplemented with the NVG resolution chart, the mean NVG acuity averaged 20/45.1. The best NVG acuity (M = 20/37.5) was obtained after participation in the NVG adjustment class.

Dyer, Smith, and McClure (1995) found that NVG visual acuity improved with experience. Over a three-day period, soldiers used the Air Force's NVG resolution chart to adjust their goggles before firing the M16A2 rifle. "On the first night, some gave inconsistent acuity readings with the chart; there were fewer problems the second night; on the final night all provided consistent readings. The average acuity on the three nights was 20/47, 20/43, and 20/41 respectively. Only on the last night did each soldier achieve consistent readings of 20/45 or better" (p. 36). Thus, it appears that the proper training in conjunction with practice and feedback is necessary to enable NVG users to achieve good acuity readings.

Research Purpose

The research examined the effectiveness and utility of different field-expedient objects to focus upon when setting the NVG diopter rings. The impact of instruction on proper NVG adjustment procedures followed by practice and feedback was also examined. The intent was to make initial recommendations regarding the field-expedient techniques which are most likely to yield the best levels of visual acuity, are easiest to use, and are tactically sound.

Method

Participants

A total of 15 soldiers from the Army's 82d Airborne Division at Fort Bragg, NC participated. Demographic data on these soldiers are in Table A-1. A diversity of duty positions was represented, with two-thirds being Infantrymen (11B, basic Infantryman; 11C, indirect fire Infantryman; 11H, heavy antiarmor weapons Infantryman). The others were two communication specialists, a mechanic, a driver, and a finance clerk. The soldiers had an average of 2.7 years of military service.

All soldiers had used either the AN/PVS-7A or 7B NVGs. Only 40% had received formal instruction on NVGs. Soldiers were asked what percentage of nights they used NVGs when executing night training exercises. Forty percent, all Infantrymen, indicated they used NVGs on 90% to 100% of the nights; one-third, a mixture of Infantrymen and nonInfantrymen, used NVGs on about half the nights; 27%, all nonInfantrymen, used NVGs on one-third of the nights. All but three soldiers indicated they typically used a tree or a treeline to focus their goggles.

The research was conducted on three consecutive nights with the same soldiers participating each night. All 15 soldiers were present on the last two nights; on the first night 14 of the 15 participated. Soldiers were to have had the same NVGs each night, but this occurred on the last two nights only.

Apparatus

A night vision goggle test set, developed by Hoffman Engineering Corporation in Stamford, CT (Model ANV-20/20) in response to a request from the Air Force's Armstrong Laboratory at Williams Gateway Airport, AZ, was used to assess the visual acuity achieved with the NVGs at the infinity focus setting. This instrument allows the user to check both the high- and low-light level resolution of a pair of NVGs (Hoffman Engineering, 1995, June). The high-light level setting is equivalent to viewing average terrain (30 to 50% reflective) under quarter-moon illumination. Low-light level refers to simulated clear starlight conditions. Visual acuity achieved by the user's diopter setting is determined by using the high-light level. The NVG test set can be used with both binocular and biocular systems, but was designed with two reticles to accommodate a binocular system, having two reticles in the viewing port. To facilitate use with the biocular AN/PVS-7 system, half the viewing port for the goggles was covered to ensure the user looked directly at a single reticle in the test set.

Visual acuity is assessed with the reticle multi-bar pattern shown in Figure 2. The numbers in the center of the squares in the reticle are the second part of the standard Snellen resolution fraction, that is, the 25 pattern represents Snellen 20/25; the 40 pattern, Snellen 20/40. The NVG user indicates the square with the smallest number where both the vertical and horizontal bars are discernible. This reading is then the visual acuity of the system. Thus a reading of 20/40 means that, under high-light level conditions at night, a trained NVG user can resolve a Snellen 20/40 target using standard goggles. The dark and and light lines in the squares of the reticle as seen through NVGs are the reverse saturation of that shown in Figure 2. Thus the numbers, e.g., 25, 30, 35, appear light or white and the dark horizontal and vertical lines as light. The background within each square is dark.

One problem with the reticle is that the Snellen increments are not constant, increasing by 5 from 20/25 through 20/50 and by 10 from 20/50 through 20/70. In addition, the upper limit is 20/70. No exact acuity assessment is possible if a NVG user cannot discern the vertical and horizontal lines in the 20/70 square.

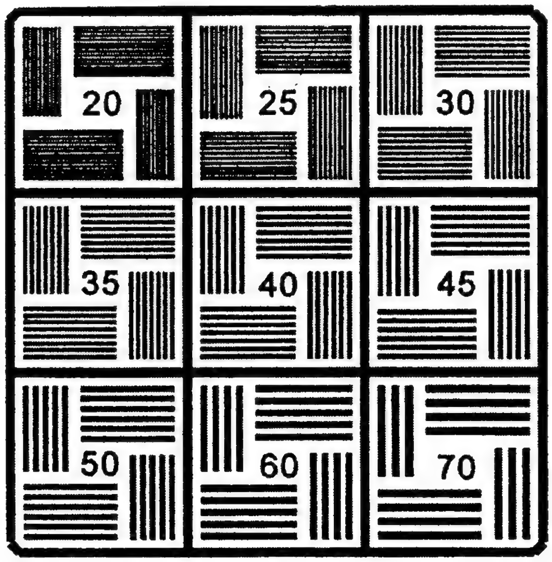

Figure 2. NVG test set reticle.

The test set can also be used to adjust the diopter rings of the NVGs. When used for this purpose, the diopter ring corresponding to each eye is set independently. The acuity reading with both eyes should be at least as good as that achieved through each eyepiece. Lastly, the test set can check the dynamic range of the NVGs; that is, whether the image intensification tube can perform in both high- and low- light level conditions. This is done with the gray scale surrounding the reticle (Figure 3). The useful range of light levels for the tube is determined by noting the contrast between adjacent segments in the gray-scale pattern. In the high-light level mode, all eight of the gray scale steps should be discernable; in the low-light level mode, steps one through six.

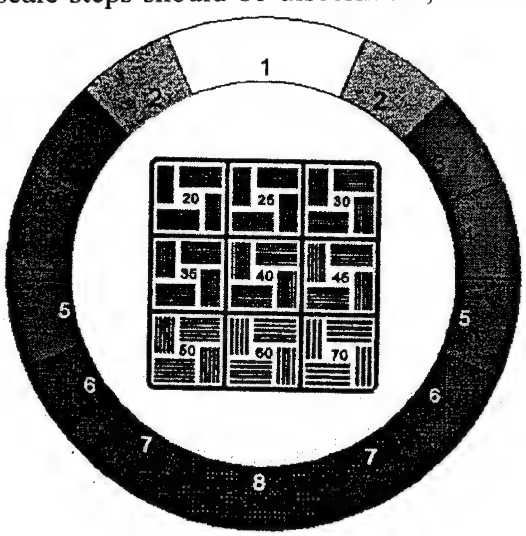

Figure 3. NVG test set gray scale.

In our initial work with the NVG test set reticle, we found that individuals could detect differences in distinctiveness and clarity among the lines within a specific square from measurement to measurement. This suggested that individuals may be able to discriminate finer differences in visual acuity than measured by the Snellen increments of the reticle. Therefore, the soldiers were asked to rate the clarity of the lines using the following 4-point scale: "Using the scale below, please rate how clearly you were able to see the lines in the pattern for your best reading: 1 (fuzzy, but can still distinguish direction of lines), 2, 3, 4 (very sharp)."

Photometric readings were taken every 5 or 10 min each night during the time period when soldiers adjusted their NVGs. Two portable photometers were used; each was mounted on a tripod. One photometer was calibrated to measure the spectrum of electro-magnetic energy (380 to 780 nanometers) visible to the human eye under night time conditions (Model TSP-410, Hoffman Engineering, Stamford, CT). This was a standard low-light level photometer. The other photometer (Model ANV-410U, Hoffman Engineering) was calibrated to measure parts of both the visible and near infrared (IR) spectrums (570 to 1050 nanometers) detected by the unfiltered, third-generation AN/PVS-7A and 7B goggles. This calibration was based on data from Stefanic (1989). Both photometers provided light readings in terms of the metric milliLux.[1]

Procedure

Overall Design. The research had three phases; each executed on a different night. On the first night, a baseline measurement of NVG visual acuity was taken, followed by training and practice on NVG adjustment procedures, and a re-assessment of the baseline measurement. On the second night, soldiers adjusted their NVGs using 15 field-expedient objects in order to determine which objects provided the best acuity. On the third night, soldiers' NVG visual acuity with the six objects which had produced the best acuity on the second night was re-examined. Soldiers were also interviewed regarding their preferences for and reactions to the field-expedient objects and their memory of the NVG adjustment procedures on which they were trained the first night.

Baseline Measurements, Training, and Practice - Night 1. On the first night, soldiers received an overview of the purpose of the research and what they would be doing each night. Their NVGs were checked by the research staff with the NVG test set to determine if at least 20/40 visual acuity was possible. All goggles were satisfactory.

[1] Both photometers used a silicon photodiode and provided a digital display of the degree of illumination incident upon this detector in terms of milliLux (Hoffman, 1995, February; 1995, May). One milliLux is equivalent to .0000929 foot-candles. A reading of .0022 Lux (2.2 milliLux) can be considered starlight. As the ANV/410U photometer assesses the near infrared spectrum, its reading in milliLux is not directly translatable to foot-candles nor to other descriptors of visible light such as starlight or moonlight. However, the readings can provide comparative information on the amount of near infrared energy in the sky across time on a given night and across nights.

The NVG test set was then explained. Each soldier examined the reticle in the test set once with a pair of NVGs, pre-adjusted to 20/40, to become familiar with the reticle pattern and measurement procedure. A baseline NVG acuity measurement was then obtained. Next, soldiers adjusted their NVGs as they would normally in a field setting, using the objects present in the training area. Their NVG visual acuity was then assessed with the test set. All soldiers were interviewed to document how they adjusted their NVGs for this baseline measurement.

Soldiers were then instructed on the NVG adjustment procedures outlined below. It is important to note that the AN/PVS-7A and 7B goggles have no markings to indicate the diopter ring and eye span (IPD) settings.

The instructions included only the steps critical to visual acuity adjustments and were based on Air Force procedures. However, the procedures for using light sources were developed during our pilot work. No instructions were provided on inspecting and mounting the goggles, as it was assumed soldiers knew these procedures. The four NVG components involved in obtaining a good visual acuity setting are the head mount, the eyepieces, the objective lens focus knob, and the diopter rings. The instructions related to these components were:

First, set the eye relief, that is, the distance of the eyepieces from the eyes. The eyepieces should not touch eye lashes or corrective glasses. Depress the socket release button on the head mount and move the goggles toward the eyes.

Second, set the eye span (the IPD), so the distance between the two eyepieces corresponds to the distance between the two eyes. Set for each eye separately.

> The starting point is to move the eyepieces as far apart as possible, to the edges of the goggles. Then close one eye. Move the eyepiece for the open eye inward toward the center of the goggles until the image with that eye is a full circle, not an oval. There should be no blurred edges. Repeat the process for the other eye.

Third, select the object which will be used when adjusting the diopter rings.

Fourth, set the focus with the objective lens focus to make the viewed object as clear as possible. The objective lens focus only adjusts for distance. It does not affect the visual acuity setting of the NVGs.

Fifth, set the diopter ring for each eyepiece. Set for each eye separately.

> Close one eye. For the open eye, turn the diopter ring to the left (counterclockwise) until it stops. Stop for a second, blink, and let the eye relax. Slowly turn the diopter ring back to the right (clockwise) until the image just becomes sharp. Stop. Do not turn the diopter ring beyond this point. If a light source is used for focusing, turn back to the right until the bloom is minimized, and then stop. If the source has a double bloom, that is, a center point of light and

a larger surrounding bloom, rotate the diopter ring back to the right until the center light source is as small as possible. Be sure to make it circular.

Repeat these procedures with the other eye.

Do not rotate the diopter rings to the right (clockwise) beyond the setting that just brings the image into sharp focus or makes the central bloom as small a circle as possible. If the rings are rotated too far to the right, the eye will initially adapt to this setting, but will become fatigued over time. Eyestrain and loss of visual acuity and depth perception will result.

Sixth, check the objective lens focus. Readjust if necessary.

Seventh, repeat steps five and six if necessary. Do not readjust the diopter rings once good visual acuity has been achieved. However, the objective lens focus should be readjusted in the field to accommodate to the distance at which objects are viewed.

Soldiers practiced these procedures using four different objects: the test set itself, a 25 in. (63.5 cm) square chart with black and white horizontal lines (1.375 in. [3.5 cm] wide), a green cyalume chemical light stick (chem light), and another soldier. The chart was developed by the Air Force's Armstrong Laboratory. It was placed 54 m from the soldier; if the soldier could distinguish the lines, the resulting NVG acuity was 20/45. The sequence in which the test set, chart, chem light, and soldier were viewed was randomized across soldiers. Visual acuity readings were taken after each soldier viewed each object. Finally, the visual acuity with the baseline object was reassessed. Photometry readings were taken every 10 min.

Assessment of Visual Acuity Readings - Night 2. On the second night, soldiers adjusted their NVGs on 15 different objects using the procedures on which they had been trained the previous night. These objects were of two types: light sources and non-light sources, often terrain features. The light sources were stars, IR chem light, red chem light, blue chem light, standard Army elbow flashlight with red filter, the standard flashlight with a NVG compatible filter, and a Phoenix IR transmitter. All chem lights were 6 in. (15.2 cm) long. The wrapping on the chem lights was split so only the round tip of the light was exposed. The non-light sources were a tree trunk, tree branches silhouetted against the night sky, a tree line, a vehicle (High Mobility Multi-purpose Wheeled Vehicle, the HMMWV), a camouflage net placed over small trees and shrubs, a sandy vehicle trail within grassy terrain, and an 8.5 in. x 11 in. (21.6 cm x 27.9 cm) piece of white paper.

These objects were selected for study because they are available to soldiers in field settings and none requires special materials or preparation. Light sources were included because during earlier NIGHTFIGHTER research we discovered that some experienced soldiers and aviators used stars to adjust their goggles. For purposes of the current investigation, several light sources were examined. Some sources, which created focusing problems in the pilot work (such

as the red filter on the flashlight), were deliberately included to determine if soldiers discriminated them from the others.

Some objects were viewed from within the infinity distance setting of 30 ft (9.1 m) of the NVGs; others at the infinity distance. The tree trunk, white paper, camouflage net, and one blue chem were all viewed from a distance of 5 m. All other objects, except the stars and tree line were viewed from a distance of 20 m; this included a second blue chem light. The exact distance to the tree line was not assessed, but it was greater than 20 m. Stakes were put in the ground to indicate where each soldier should stand when viewing each object. All lights, plus the white paper, were also placed on stakes. The entire chem light was not exposed. To produce a small source of light, the wrapper was left on body of the chem light and torn to expose only the round end of the light. The soldiers viewed the 15 objects according to a randomized Latin square design.

Visual acuity measures were taken with the NVG test set and assessed after each object. After each visual acuity reading, the diopter rings were rotated to a random position, requiring soldiers to adjust the rings from a different starting position with each object. Photometric readings were collected every 10 min while soldiers adjusted their goggles.

Re-assessment of Visual Acuity Readings - Night 3. On the last night, soldiers were first interviewed on their preferences for the 15 objects used the previous night (see questions in Appendix A). Soldiers were asked whether their experience with the 15 objects changed what they would use for focusing their NVGs in the future; which objects they preferred for focusing; which objects they liked the least; whether they noticed a change in the ability to see clearly with NVGs as a result of the procedures on which they had been trained; and what they learned about adjusting NVGs that they did not know previously. To check on the adequacy of the training, they were asked to repeat the NVG adjustment procedures they had been taught.

Then they adjusted the diopter setting on their NVGs by focusing on the six objects for which the best acuity ratings were achieved the previous night. These six objects were the tree trunk, IR chem, vehicle trail, vehicle, blue chem (close), and stars. Half the soldiers viewed the objects in this order; half in the reverse order. As visual acuity readings with the blue chem were identical for the close and far distances, the close distance was chosen for convenience and tactical considerations. After each visual acuity reading, the diopter rings were rotated to a random starting position. Photometric readings were taken approximately every 5 min.

Following these assessments, soldiers rank ordered the six objects on the ease of adjustment and usability in the field The ease of adjustment question was:

> "Which of these objects was the <u>easiest</u> for you to determine if you had a <u>good acuity adjustment</u>? Rank the objects from the easiest to adjust to the hardest to adjust. Assign a 1 to the easiest object. Consider such factors as the speed with which you made the adjustment, and whether you had to repeat any steps."

The usability question was:

> "Practically speaking, which of these objects is the most usable in the field? Rank the objects from the most usable to the least usable. Assign a 1 to the most usable object. Consider such factors as whether the object is usually available to you in the field, whether use of the object is consistent with your SOP on light discipline, and whether you can make the adjustment in most locations without assistance from others."

Results

The visual acuity reading was the critical measure of perfomance. However, a discrimination index was generated to determine if a mathematical combination of the visual acuity readings and clarity ratings would yield improved discrimination among the objects. To combine the two measurements, the visual acuity readings were multiplied by 10. In other words, a 20/45 reading was changed to 450 points; a 20/60 rating to 600 points. The clarity ratings, originally obtained on a one- to four-point scale, were then transformed to divide the intervals between the revised visual acuity readings (the intervals were either 50 or 100 points) into equal segments. The discrimination index was the sum of the transformed acuity readings and clarity ratings. Thus if two soldiers had a 20/45 visual acuity reading, yet one stated that the lines were very sharp and the other that the lines were fuzzy, the first soldier's discrimination index would reflect a clearer image than the second soldier's index. However, the index did not provide improved discrimination among the objects. For each source, the correlations between the visual acuity reading and the discrimination index were .95 or higher. Thus, no further analyses were made with the discrimination index.

Baseline and Training Measures - Night 1

The initial baseline measure was taken at 8:15 p.m.; the visual acuity measures for the objects and the reassessment of the baseline occurred from 9:00 to 9:30 p.m. The sky was clear with stars present; there was no moon. At 8:15 p.m. the light photometer registered 33.8 milliLux. From 9:00 to 9:30 p.m., it dropped from 19.2 to 18.2 milliLux. The near IR readings dropped from 9.5 to 5.

The initial baseline measure assessed the visual acuity soldiers currently attain in the field. Eighty percent focused on a treeline or a tree; the remainder (20%), on the portajohns in the training area. All objects were at least 30 ft (9.1 m) away. Three soldiers examined a second object to verify the sharpness of their NVG image. After this assessment, soldiers were instructed on proper adjustment procedures and practiced these procedures on four objects. At the end, the baseline measurement was repeated. Mean acuity readings for all objects are in Table 2. A t-test for dependent samples comparing the initial baseline reading to that obtained after training and practice showed a significant improvement on the visual acuity measure, $t(13) = 4.02$, $p < .004$. One soldier whose acuity was worse than 20/70, was scored as 20/70, as that was the upper limit on the NVG test set. The standard deviations in Table 2 indicate the variability in acuity readings was reduced by two-thirds after the training.

Correlations among the visual acuity measures are in Appendix A. The initial baseline reading did not correlate with any of the other measures. Of the ten correlations among the other objects, seven were significant ($p < .05$, one-tailed test), being at least .46. All ten were higher than the correlations involving the initial baseline reading[2].

For the initial baseline measurement, only 21% of the soldiers stated they adjusted the eye span on the NVGs before sighting in on an object. However, all adjusted the objective lens at some point to get the sharpest image of the viewed objects. Seventy-nine percent stated they adjusted the diopter rings and closed each eye separately during the adjustment procedure. Only 29% rotated the diopter adjustment ring counterclockwise and then back clockwise to get the best acuity. Only one soldier adjusted the NVGs according to the sequence of steps provided in the instructions which followed.

Table 2
Mean Visual Acuity on Baseline and Practice Objects

Object	Visual Acuity	
	M	*SD*
Baseline Prior to Training	47.50	10.14
Practice Objects		
Test Set	41.43	4.57
Chart	38.57	6.91
Soldier	38.57	6.33
Green Chem	40.00	8.55
Baseline After Training	36.79	3.72

Visual Acuity Readings - Night 2

The visual acuity measurements were taken from 8:00 to 8:55 p.m. The sky was cloudy; only a few stars were visible; there was no moon. Sky conditions were quite variable, as a storm was approaching and rain occurred a quarter-mile from the training site. The visible photometric readings dropped rapidly and steadily at 8:00 p.m., making it impossible to get a constant reading. Within a minute, the readings dropped from 490 to 310 milliLux. From 8:10 to 8:55 p.m. the reading leveled off, dropping from 54 to 43 milliLUX. The near IR readings dropped from 18 to 14 milliLux.

Mean visual acuity readings for the field-expedient objects are in Table 3. Separate single-factor repeated measures analyses of variance (ANOVA) were conducted for the light

[2] The small sample size may have affected the magnitude of the correlation coefficients.

sources and the non-light sources[3]. There was no significant difference in the mean visual acuity readings for the light sources, $F(7, 98) = .99, p = .447$. There was a significant difference for the non-light sources, $F(6, 84) = 2.33, p < .04$, but from a practical perspective the differences in mean acuity were small.

Correlations among the visual acuity readings are in Appendix A. The average correlation among the light sources was .69; the average correlation among the non-light sources was .49.

Table 3
Mean Visual Acuity on Field-Expedient Objects

Object	Visual Acuity	
	M	*SD*
Light Source		
IR chem	36.33	3.62
Stars	37.00	3.62
Blue chem, close	37.00	5.28
Blue chem, far	37.00	5.28
Flashlight - NVG filter	38.00	5.61
Red chem	38.00	5.61
Flashlight w red filter	38.33	4.88
Phoenix Transmitter	38.67	5.16
Non-light Source		
Tree Trunk	35.33	3.52
Vehicle	36.67	4.88
Trail	36.67	4.88
Tree Line	37.33	4.17
Paper	37.33	5.30
Camo net	37.67	3.72
Tree Silhouette	37.67	5.50

Re-assessment of Acuity Readings - Night 3

Before re-assessing the visual acuity achieved with the six objects which yielded the best acuity on the second night, the soldiers were questioned on NVG adjustment procedures and on preferences for the 15 objects used previously. All but two of the 15 soldiers stated they would

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[3] A singular matrix resulted when using repeated measures, multivariate ANOVA subroutines to compare mean ratings on all objects. Two ANOVAs were conducted to eliminate this problem, one for the light sources and one for the non-light sources .

continue to focus their NVGs on tree lines. The remaining two indicated they would use a chem light or a vehicle. Eight soldiers cited objects they would use in addition to tree lines, specifically, a vehicle, IR chem, a person, and a mortar.

When asked which of all the 15 objects they preferred the most, half cited non-light sources and half cited light sources. There was no strong preference for any individual object. Two soldiers cited two sources each (vehicle and people, stars and red chem). Four objects were never cited: the flashlight with the red and NVG-compatible filters, the paper, and the tree silhouette.

Light sources (red filter on the flashlight, stars, chem lights) were the least preferred objects to use when focusing the goggles, being mentioned in 83% of the responses, with some soldiers mentioning more than one object. The flashlight with the red filter constituted 50% of all responses. The negative reaction to the red flashlight filter was consistent with pilot test results. Light sources were typically too intense, making it very difficult to reduce the bloom in the NVGs. One soldier, however, indicated that the blue chem light was too dim. Two non-light sources were mentioned, the white paper and the trail. The paper was viewed as impractical in a field environment; the trail, as not producing a sharp image.

Eighty percent of the soldiers perceived an improvement in their ability to see as a result of the new procedures. Most (87%) indicated they learned something new about either the diopter adjustments (42% of the responses) or the eye span adjustment (42% of the responses). These responses were consistent with the steps and procedures soldiers omitted when making the baseline NVG adjustments on the first night.

In general, the soldiers repeated the NVG adjustment procedures given during the instructions. Eighty percent stated to adjust the eye span. All cited the objective lens and the diopter adjustments. However, only half mentioned the need to adjust the diopter rings for each eye independently and only half cited the direction in which the diopter rings should be rotated. These omissions could reflect the open-ended nature of the interview question or the failure of the research staff to explain that a complete, detailed response was desired. One error was clear, however, indicating a need to refine the training package. Half the soldiers stated, incorrectly, that the diopter adjustments should always be made before adjusting the objective lens for distance. Only two soldiers described all steps completely and cited them in the correct sequence.

On the last night, the visual acuity measures were taken every 5 min from 8:05 to 8:20 p.m. It was a partially cloudy night with some stars; there was no moon. Visible photometric readings dropped steadily over the 15 min period, from 72 to 21 milliLux. The near IR readings dropped from 30 to 6.34 milliLux.

The visual acuity results on the six objects are shown in Table 4. Mean readings ranged from 20/35 to 20/37, the same range achieved on the previous night with the same objects. There were no significant differences among the mean visual acuity ratings, $F(5, 70) = 1.14$, $p < .347$

(single-factor repeated measures ANOVA). The correlations among these ratings are in Appendix A, with the mean correlation being .70.

Soldiers rank ordered the six objects which had received the best acuity ratings on the second night on two dimensions: ease in determining a good acuity adjustment and usability in the field. The mean rank for each object was computed on each dimension and is displayed in Table 5. In addition, the data were subjected to the Friedman multi-sample test to determine if there were significant differences in the ranks. For both dimensions significant differences occurred, $\chi^2(5) = 24.52, p < .0002$ for ease and $\chi^2(5) = 43.68, p < .0001$ on usability.

Table 4
Re-assessment of Visual Acuity on the Six Best Field-Expedient Objects

Object	Visual Acuity	
	M	*SD*
Light Source		
Blue Chem, close	35.33	4.88
Stars	35.33	4.14
IR Chem	36.67	3.52
Non-light Source		
Vehicle	36.33	2.97
Trail	36.33	3.99
Tree Trunk	37.33	4.58

Table 5
Mean Rank on Ease of Determining Good Acuity Adjustment and on Usability Dimensions

Dimension	Object					
	Tree Trunk	Vehicle	Trail	Stars	IR Chem	Blue Chem
Ease of Determining Good Adjustment	1.8	2.5	4.0	4.0	4.4	4.3
Usability in the Field	1.4	2.7	3.2	3.6	4.9	5.3

Note. A rank of 1 indicates the easiest object on which to make adjustments and the most usable in the field.

The tree trunk was perceived as the easiest object for focusing NVGs and was ranked as the most usable in the field. Second on both dimensions was the vehicle. The trail, stars, and both chem lights all received low and equivalent ranks on the ease of determining a good visual acuity setting. However, there was some discrimination among these objects in terms of

usability in the field. Both the trail and stars were perceived more favorably than the two chem lights, the only two artificial light sources.

Discussion

Acuity Levels

The absolute level of the visual acuity readings obtained in this research after training and practice was extremely good, approaching the upper limits of the image intensification technology in the NVGs. They were superior to readings found in prior research using the NVG resolution charts (DeVilbiss & Antonio, 1993; DeVilbiss, Antonio, & Fiedler, 1994; Dyer, Smith, & McClure, 1995). It is believed that these absolute values were affected by the design of the reticle in the NVG test set and other aspects of the assessment protocol.

The measurements of visual acuity relied on self-reports, which are susceptible to biases (Runkel & McGrath, 1972). Soldiers were asked to report the lowest visual acuity reading (e.g., 35, 40, 45) corresponding to the square in the reticle containing discriminable horizontal and vertical lines. Given that there was no clear distinction between discriminable and nondiscriminable lines, soldiers may have been biased to report an acuity reading that was better than their "true" acuity. The possibility for this bias may have also been enhanced by the effects of reporting acuity measurements in a group context and the tendency for positive self-presentation, despite efforts to minimize these effects via instructions.

Biases for reporting better acuity measurements may be attenuated by redesigning the way in which visual acuity is measured with the test set and how measurements are reported. Several proposals are suggested. First, the numbers within the reticle representing visual acuity could be replaced by arbitrary designations such as letters which do not provide information about the scale of measurement. Also, the squares corresponding to a particular level of visual acuity could be displayed in random positions to eliminate position biases. Another suggestion is to rearrange the orientation of the lines within the squares of the reticle, such that orientations vary across the squares corresponding to particular levels of visual acuity and require soldiers to describe the orientation of the lines.

No matter how the 3 x 3 display is constructed, a more definitive indication of visual acuity would be to have individuals count the number of vertical and horizontal lines in each square. This assessment would provide a less subjective assessment of the clarity and sharpness of the image seen by the soldier. In a pilot test of this procedure, individuals found it extremely difficult to count the number of lines below a 20/45 reading, even though the lines could be discriminated. However, the procedure could be implemented as check on possible bias in readings, particularly when an extremely good reading is given.

Another alternative involves a more radical redesign of the reticle so it contains 16 (4 x 4) or 25 (5 x 5) squares. Each square would contain either horizontal or vertical lines. These vertical and horizontal grating patterns (16 or 25) would correspond to different levels of Snellen visual acuity and be displayed randomly. Soldiers would indicate the orientation of the lines

within each square. No label indicating the acuity associated with each square would be presented. Only the trainer or individual assessing the acuity would have this information. Thus the display would be similar to that shown in Figure 1. Sufficient grating patterns would be displayed to allow constant increments in the Snellen equivalents presented. Furthermore, with this design, repeated assessments of visual acuity could be obtained by having the soldier look at the reticle from four different positions. This would also reduce possible biases in the readings.

In addition to redesigning the measurement apparatus, efforts need to be made to minimize the effects of social influence on self-reports. This can be accomplished by arbitrary designations of the visual acuity measurement reported or by unmarked designations, and by having individuals report their acuity in a way which guarantees others do not know what is reported.

Individual differences in soldier ability to achieve good NVG adjustments were observed. Visual factors, such as contrast sensitivity, which may correlate with these differences should be considered in follow-on experiments.

The effects of instruction versus instruction with practice and feedback was not assessed with the experimental design. However, we believe the practice combined with feedback on the first night contributed to the improved baseline visual acuity measures, and that this effect would not have been as strong if only instructions had been given. Given the improvement in NVG acuity with practice observed by Dyer, Smith, and McClure (1995) with soldiers who had used NVGs less than the soldiers in the current research, the effect of practice may be even greater with soldiers with minimal or no NVG experience. Soldiers may need performance feedback in order to learn just how sharp and clear NVG images can be.

Field-Expedient Objects

Clearly, there was little discrimination in the visual acuity readings obtained with the different field-expedient objects. As stated above, this may be a result of the design of the NVG test set. However, soldiers did prefer certain objects. They favored the tree trunk for both ease of adjustment and usability in the field. Trees are found in many field settings, and they do not present a tactical problem. Vehicles were probably rated highly for similar reasons. In general, most of the negative reactions dealt with light sources, because of the difficulty in reducing the bloom to get a good adjustment, as well as the fact that they can constitute violations of light discipline during night operations. Given the cloudy nights on which the adjustments were made, soldiers never had a good opportunity to evaluate stars. Another factor which may have influenced soldier preferences was the extent to which certain objects had been used habitually when adjusting NVGs. Past experience may have also contributed to the tendency to favor trees.

It was expected that soldiers would react negatively to the red light sources, as the resultant NVG bloom is considerable. Soldiers indicated the bloom was large, but apparently it did not affect their NVG acuity substantially. It should be noted that most soldiers were motivated to do well, trying to get good acuity readings with each object.

Employing Proper NVG Visual Acuity Adjustment Procedures

Findings related to the initial baseline assessment showed clearly that many of the soldiers did not know how to adjust critical NVG components, specifically, the eyepieces and the diopter rings. They were unaware of the proper techniques, which resulted in inadequate levels of visual acuity. These findings were not unexpected, as the NVG TMs and other training materials for ground forces omit essential information on adjustment procedures and techniques.

Finally, executing the proper procedures was not difficult. As soldiers gained expertise in making adjustments, they were able to do them very quickly.

Summary and Conclusions

The field-expedient objects examined in this research did not produce large average differences in visual acuity readings. However, when these findings were combined with the variability in visual acuity readings the soldiers obtained across sources, soldier preferences, and other reactions to the objects, a clearer picture emerged. Based on all factors, the best field-expedient objects were a tree trunk, a vehicle, a vehicle trail presenting a good contrast against its surroundings, stars, IR chem light , and a blue chem light. Objects which are not recommended at this time include the red filter in the standard Army flashlight, a red chem light, the Phoenix transmitter, a flashlight with a NVG compatible filter, a piece of white paper, and a tree silhouette. More information is needed on the usefulness of a treeline and a camouflage net.

Before conclusive recommendations are made regarding the best field-expedient objects, the research should be replicated with other populations of soldiers under differing ambient light conditions using a modified NVG test set, to reduce possible biases toward good acuity readings, and with modified self-report procedures, to reduce biases toward positive self-presentation. An experiment examining the effects of instruction combined with practice and feedback versus instruction only should also be conducted.

Given that at least a 25% improvement in visual acuity resulted from the instructions and accompanying practice and feedback, it is apparent that soldiers can achieve better visual acuity with their NVGs than is currently the case. Complete instructions for the recommended adjustment procedures are at Appendix C. These procedures should be disseminated to ground forces and included as a change to the NVG TMs.

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APPENDIX A

DATA

Table A-1

Demographic Information and Experience with NVGs

ID	Months in Service	Duty Position	Months in Duty Position	NVGs Used	% Nights use NVG	Formal NVG Training	Objects Focus On
1	48	60mm Mortar Gunner	18	7A/7B	100%	No	Treeline
2	18	SAW Gunner	1	7B	50%	No	Tree
3	36	Dragon Gunner	6	7A/7B	90%	No	Tree/Leaves
4	108	Squad Ldr	18	7A/7B	50%	Yes	Woodline
5	24	81mm Mortar Gunner	2	7A/7B	100%	No	Tree
6	14	M60 Asst Gunner	2	7B	100%	No	Trees
7	18	Automatic Rifleman	8	7A/7B	90%	No	Woodline
8	8	Driver (2 ½ ton)	3	7B	50%	No	Ground
9	36	Mechanic (5 ton & below)	30	7A/7B	30-40%	Yes	Something 10 ft away
10	42	Finance Clerk	30	7A/7B	30%	No	Partner
11	20	Rifleman	1	7B	70%	Yes	Tree
12	24	Commo (Ops & Maint)	18	7A/7B	40%	No	Tree
13	13	Commo	5	7B	25%	Yes	Treeline
14	15	M60 Gunner	7	7A/7B	100%	Yes	Treelimbs/ Buddy
15	60	TOW Gunner	12	7A	50%	Yes	Tree trunk

Table A-2

Frequency Distribution of Visual Acuity Readings - Night 1

Object	Visual Acuity Reading							
	30	35	40	45	50	60	70	70+
Baseline	0	2	3	3	3	2	0	1
Test Set	0	3	5	5	1	0	0	0
Chart	3	4	5	0	2	0	0	0
Soldier	2	5	4	1	2	0	0	0
Green Chem	2	5	3	1	2	1	0	0
Re-assess Baseline	1	8	4	1	0	0	0	0

Note. $N = 14$.

Table A-3

Frequency Distribution of Visual Acuity Readings - Night 2

Object	Visual Acuity Reading					
	25	30	35	40	45	50
Light Source						
IR Chem	0	2	8	4	1	0
Blue Chem, close	0	2	8	3	1	1
Stars	1	1	7	3	3	0
Blue Chem, far	0	2	8	3	1	1
Flashlight w NVG Filter	0	2	6	4	2	1
Red Chem	0	2	6	4	2	1
Flashlight w Red Filter	0	0	9	3	2	1
Phoenix Transmitter	0	1	6	5	2	1
Non-light Source						
Tree Trunk	0	3	8	4	0	0
Vehicle	1	1	6	6	1	0
Trail	0	2	8	4	0	1
Tree Line	0	1	8	4	2	0
Paper	0	2	7	4	1	1
Camouflage Net	0	1	6	7	1	0
Tree Silhouette	0	0	7	4	2	2

Note. $N = 15$.

Table A-4

Frequency Distribution of Visual Acuity Readings - Night 3

Object	Visual Acuity Reading				
	30	35	40	45	50
Blue Chem, close	3	9	2	1	0
IR Chem	1	10	3	0	1
Stars	4	7	3	1	0
Tree Trunk	1	8	4	2	0
Vehicle	2	8	4	1	0
Trail	1	9	5	0	0

Note. $N = 15$.

Table A-5

Rank Order on Ease of Determining Good Acuity Adjustment

ID	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6
1	Tree Trunk	Blue Chem	IR Chem	Vehicle	Stars	Trail
2	Vehicle	Tree Trunk	Stars	IR Chem	Blue Chem	Trail
3	Stars	Blue Chem	IR Chem	Vehicle	Tree Trunk	Trail
4	Tree Trunk	Vehicle	Trail	IR Chem	Blue Chem	Stars
5	Tree Trunk	Vehicle	Trail	Blue Chem	IR Chem	Stars
6	Tree Trunk	Vehicle	Stars	IR Chem	Blue Chem	Trail
7	Tree Trunk	Trail	Stars	IR Chem	Vehicle	Blue Chem
8	Vehicle	Tree Trunk	Trail	Stars	IR Chem	Blue Chem
9	Tree Trunk	Vehicle	Stars	IR Chem	Blue Chem	Trail
10	Trail	Tree Trunk	Vehicle	Stars	IR Chem	Blue Chem
11	Tree Trunk	Vehicle	Stars	Trail	Blue Chem	IR Chem
12	Vehicle	Tree Trunk	Trail	Blue Chem	Stars	IR Chem
13	Blue Chem	Tree Trunk	Trail	Vehicle	IR Chem	Stars
14	Tree Trunk	Blue Chem	IR Chem	Vehicle	Trail	Stars
15	Vehicle	Stars	Trail	Tree Trunk	IR Chem	Blue Chem

Note. A rank of 1 indicates the easiest object to adjust to a good acuity reading; a rank of 6, the hardest object to adjust.

Table A-6

Rank Order on Usability in the Field

ID	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6
1	Tree Trunk	Stars	Vehicle	Trail	IR Chem	Blue Chem
2	Tree Trunk	Vehicle	Stars	Trail	Blue Chem	IR Chem
3	Tree Trunk	Trail	Vehicle	Stars	Blue Chem	IR Chem
4	Tree Trunk	Trail	Stars	Vehicle	IR Chem	Blue Chem
5	Tree Trunk	Vehicle	Trail	IR Chem	Stars	Blue Chem
6	Tree Trunk	Vehicle	Stars	Trail	IR Chem	Blue Chem
7	Tree Trunk	Stars	Blue Chem	Trail	Vehicle	IR Chem
8	Trail	Vehicle	Tree Trunk	Blue Chem	IR Chem	Stars
9	Tree Trunk	Vehicle	Stars	IR Chem	Trail	Blue Chem
10	Tree Trunk	Trail	Vehicle	Stars	IR Chem	Blue Chem
11	Tree Trunk	Trail	Stars	Vehicle	IR Chem	Blue Chem
12	Vehicle	Tree Trunk	Stars	Trail	IR Chem	Blue Chem
13	Tree Trunk	Vehicle	Trail	IR Chem	Stars	Blue Chem
14	Tree Trunk	Blue Chem	IR Chem	Vehicle	Stars	Trail
15	Vehicle	Trail	Stars	Tree Trunk	IR Chem	Blue Chem

Note. A rank of 1 indicates the most usable object in the field for focusing NVGs; a rank of 6, the least usable object.

Table A-7
Correlations Among Acuity Readings - Night 1

	NVG Test Set	Chart	Soldier	Green Chem	Final
Initial Baseline	-.04	.38	.12	.09	.23
NVG Test Set		.68**	.61*	.39	.52*
Chart		.	.56*	.42	.70**
Soldier				.75**	.69**
Green Chem					.42

* $p < .05$. ** $p < .01$. All one-tailed tests.

Table A-8
Correlations Among Acuity Readings for Light Sources - Night 2

	IR Chem-	Blue Chem-Cls	Blue Chem-Far	Red Chem	Red Filter	NVG Filter	Phoenix
Stars	.88***	.82***	.76***	.65**	.72**	.70**	.91***
IR Chem		.84***	.56*	.52*	.47*	.79***	.89***
Blue Chem-Cls			.49*	.45*	.69**	.75***	.83***
Blue Chem-Far				.81***	.69**	.63**	.69**
Red Chem					.46*	.72**	.64**
Red Filter						.52*	.68**
NVG Filter							.76***

* $p < .05$. ** $p < .01$. *** $p < .001$. All one-tailed tests.

Table A-9
Correlations Among Acuity Readings for Non-Light Sources - Night 2

	Vehicle	Veh. Trail	Camo Net	Tree Line	Tree Silh.	White Paper
Tree Trunk	.69**	.69**	.34	.43	.74***	.05
Vehicle		.63**	.62**	.41	.69**	.53*
Vehicle Trl.			.43	.67**	.75***	.12
Camo Net				.49*	.31	.84***
Tree Line					.50*	.30
Tree Silh.						.15

* $p < .05$. ** $p < .01$. *** $p < .001$. All one-tailed tests.

Table A-10

Correlations Between Acuity Readings for Light and Non-Light Sources - Night 2

	Tree Trunk	Vehicle	Vehicle Trail	Camo Net	Tree Line	Tree Silh.	White Paper
Stars	.51*	.85**	.65**	.75***	.55*	.54*	.67**
IR Chem	.51*	.64**	.74***	.71**	.67**	.48*	.53*
Blue Chem-Cls	.44*	.55*	.49*	.80***	.42	.39	.72**
Blue Chem-Far	.44*	.69**	.69***	.53**	.50*	.64**	.40
Red Chem	.31	.65**	.65**	.70**	.52*	.49*	.53*
Red Filter	.35	.57*	.28	.66**	.38	.44*	.64**
NVG Filter	.58*	.59*	.78***	.79***	.59*	.50*	.47*
Phoenix	.52*	.73***	.66**	.76***	.65**	.61**	.58**

* $p < .05$. ** $p < .01$. *** $p < .001$. All one-tailed tests.

Table A-11

Correlations Among Acuity Readings - Night 3

	Vehicle	Vehicle Trail	Stars	IR Chem	Blue Chem
Tree Trunk	.59*	.73**	.68**	.76***	.83***
Vehicle		.74**	.64**	.64**	.58*
Vehicle Trail			.69**	.73**	.79**
Stars				.56*	.88***
IR Chem					.69**

* $p < .05$. ** $p < .01$. *** $p < .001$. All one-tailed tests.

Procedures Used to Adjust NVGs Before Training on the First Night
[Number (#) of soldiers performing each step is shown.]

#	Step	
3	Eye span adjustment	
14	Objective focus adjustment	
11	Diopter adjustment	
	10	Adjust each eye separately
	4	Adjust counterclockwise then clockwise
1	Check objective focus again	

#	Sequence of Major Steps
6	Focus, diopter
3	Focus only
2	Eye span, focus, diopter
2	Diopter, focus, diopter
1	Eye span, focus, diopter, focus

Only 1 soldier adjusted the goggles in accordance with all procedures (including subsets for adjusting the diopter rings) cited in the training which followed.

NVG Adjustment Procedures Cited by Soldiers on the Last Night

#	Step	
12	Eye span adjustment	
15	Objective focus adjustment	
15	Diopter adjustment	
	8	Adjust each eye separately
	8	Adjust counterclockwise then clockwise
2	Check objective focus again	

#	Sequence of Major Steps
4	Eye span, diopter, focus
2	Eye span, focus, diopter, focus
2	Eye span, focus, diopter
2	Focus, diopter
1	Focus, eye span, diopter
1	Focus, diopter, focus
1	Diopter, focus, eye span
1	Diopter, focus, diopter, eye span, eye relief
1	Eye relief, eye span, diopter, focus

Only 2 soldiers repeated the adjustment procedures in accordance with all procedures (including the subsets for adjusting the diopter rings) given in the training.

Responses to Interview Questions on the Last Night

Question: All of you mentioned using trees when focusing your goggles in the field. On the basis of your experience this week, would you do the same in the future or use something else?

#	Primary Object
13	Trees or tree silhouette
1	Chem light
1	Vehicle

#	Secondary Object
2	IR chem light if available
1	Any chem light, at a distance
2	Vehicle
2	Person
1	Mortar, close

Question: Of all the objects you looked at, which do you prefer? Why? (Two soldiers cited more than one object.)

#	Nonlight Sources
3	Vehicle - Could make out definitive lines to get a clear focus - Could easily use it as well
2	Tree trunk - With lights and chem lights, wasn't sure I was getting a clear picture, but with tree trunk could tell when tuned in
1	Tree line - I could see everything far away
1	Trail - Can see what's going on; visibility clearer than focusing on trees/vehicles
1	Camouflage net - Easy to focus in on, once focused could see it clearly
1	People - Could make out definitive lines to get a good focus

#	Light Sources
2	Phoenix - Can see it only with night observation devices, can't see with unaided eye, and I got a good adjustment - Small dot as a light source and easy to get circular
1	Blue chem - Gave best test reading on the box, easy to focus on, & small bloom
1	Stars - Get a good focus with no halo
1	IR chem - Only people with NODs would be able to see it
1	Red chem - No halo
1	Any chem light - All looked the same, but most distant one had small focus point
1	No Preference

Question: Of all the objects you looked at, which do you like the least? Why? (Three soldiers cited more than one object.)

#	Nonlight Sources
2	Trail
	- Too vague, looked at blades of grass instead
1	White Paper
	- Not usable in field environment

#	Light Sources
9	Flashlight with red filter
	- Light took over the whole screen
	- Hard to focus on, didn't know when to start or stop because the bloom was so large
	- Too bright
	- Bloomed too much, overpowering
	- Very bright, blinded me, hard to focus on because so bright
	- Too much of a glare, too big a halo
	- Had a hard time trying to focus on it, too large and too bright
	- Blotted out whole picture, couldn't see what was going on
	- Big bloom
3	IR chem
	- Too bright
	- Hard to focus on, never went down to perfect circle
	- Too bright
1	Stars
	- Hard to tell when you had the best resolution
1	Blue chem light
	- Hard to see if not in the right location, light is dim
1	All the flashlights and chem lights
	- Red was the worst for the flashlights and the chem lights, couldn't bring the bloom in

Question: Have you noticed any change in your ability to see using the procedures we taught you? (Do you think you see better, no change, no worse?)

#	Response
12	Improvement
	- Can get a clearer picture now
	- Yes, got a better focus
	- A lot better
	- Can see clearer and maybe a little further
	- Can see better and adjust better
	- Better, didn't know eyepieces focused
	- Yes, didn't know how to move eyepieces
	- It helped. We don't use NODs very much, will get better with more use
	- Better; adjust diopter separately for each eye, wasn't told to do this.
	- A little bit (2 responses)
3	No change
	- No. Used that technique anyway, but took more time here
	- Can see as well but had never used the eye span
	- No change; tiny bit better

Question: What did you learn about adjusting your NVGs that you did not know previously? (Four soldiers cited more than one aspect of adjusting NVGs.)

#	Sequence	
7	Diopter Adjustment	
	2	Turn diopters counterclockwise and then bring them back
	2	Focusing diopters - rather than back and forth, turn counterclockwise and then clockwise until clear
	1	Adjust diopter rings separately for each eye
	1	Diopter adjust clarity
	1	Didn't know about diopter rings
7	Eyepieces or Eye Span Adjustment	
	3	Move eyepieces
	2	Eyepieces adjustable
	2	Eye span
1	Didn't know objective focus was for distance, thought it was for focusing	
1	Did same things as previously, just in a different order	
1	Took more time - specific steps to adjust	
2	No new information	

APPENDIX B

FIELD-EXPEDIENT OBJECTS

Object	National Stock Number (NSN)
Chem Light	
Green, 12 hour, 6 in.	6260-01-074-4229
Blue, 8 hour, 6 in.	6260-01-178-5560
Red, 30 min, 6 in.	6260-01-230-8601
Infrared, 3 hour, 6 in.	6260-01-195-9752
NVG Compatible Flashlight Filter, 1.715 in.	6230-01-369-1658
Phoenix Infrared Transmitter	5855-01-396-8732

(Pocket-size, user programmable IR beacon; invisible to the naked eye. Can program a code which will repeat every 4 sec. In the research, no code was set, thereby producing a constant beam or signal.)

APPENDIX C

NIGHT VISION GOGGLE FIELD-EXPEDIENT GUIDE FOR GROUND FORCES

NIGHT VISION GOGGLE (NVG) FIELD-EXPEDIENT GUIDE FOR GROUND FORCES

> **Do you have a blurry image through your NVGs?**
> **You may not be adjusting them properly to get the sharpest image.**
> **This guide tells you how to get a good image.**

This guide states how to adjust your night vision goggles in the field to obtain the sharpest image possible, that is, the maximum visual acuity. The information supplements current technical manuals and other training publications.

You can adjust your goggles to get a sharp image when there is good illumination at night and you follow the steps in the guide. In most cases you can get 20/40 or 20/45 visual acuity. You cannot achieve 20/20 vision with the current image intensification technology in your goggles; but you will avoid the blurry images characteristic of 20/70 acuity or worse which many soldiers experience. Proper adjustment of your goggles will also reduce eyestrain.

The steps must be executed in sequence.

The guide recommends objects to look at in the field when focusing your goggles, as these objects provide sharp images. The objects include both light and non-light sources. The guide also recommends some objects which should not be used, as they do not provide the sharpest images.

NVGs do not correct for all vision problems. They do not correct for astigmatism. If you have significant substantial astigmatism, your corrective lenses or glasses should be worn with NVGs to get the best visual acuity possible. However, you must still adjust NVGs when wearing glasses.

You need experience in looking at different objects to know when you have the best adjustment under different levels of night illumination. The visual acuity you achieve with NVGs improves with practice. Experienced users adjust their goggles quickly and easily.

The adjustment procedures are based on tests conducted by the Army Research Institute at Fort Benning, GA, and guidance developed by Army, Air Force, and Navy aviation agencies.

ADJUSTMENT PROCEDURES

1. Put on the head harness and mount the NVGs. Adjust straps to fasten head harness securely.

2. Set the eye relief --- move the goggles close to your eyes. [The eye relief is the distance of the eyepieces from the eyes.]

→ Depress the socket release button on the head mount and move the goggles toward your eyes. The eyepieces should not touch your eyelashes or corrective glasses.

3. Set the eye span --- center each eyepiece over each eye. [The eye span is the distance between the two eyepieces. It is also called the interpupillary distance or the IPD.]

→ Set the eye span to correspond to the distance between the two eyes.

→ Pull the eyepieces as far apart as possible.

→ Close one eye. For the eye which is open, move the corresponding eyepiece inward until the image you see is a full circle, not an oval. There should be no blurred images. (If you have trouble closing one eye, cover it by folding the eyecup over it.)

→ Close the other eye, and move the other eyepiece inward until the image you see is a full circle, not an oval.

4. Select an object to look at. [Select objects which provide a high-contrast or light sources whose "bloom" can be reduced.]

Recommended objects are:

<u>Tree trunk</u>. Get within 5 feet of a tree trunk and look at the bark.
<u>A vehicle</u>, positioned so you can distinguish sharp lines, corners, and other features. The vehicle can be close (within 30 ft) or farther (beyond 30 ft., at the infinity setting of the goggles).
<u>A vehicle trail</u> that stands out in its environment (for example, a white sandy trail in the middle of a grassy field).
<u>A star</u>
<u>An IR chem light</u>.
<u>A blue chem light</u>.
Chem lights can be close (within 30 ft) or far (beyond 30 ft. at the infinity distance for NVGs). Leave the wrapper on the chem light and expose only the round end of the light. Do not expose the entire chem light.

Do not look at:

A flashlight with a red filter
A red chem light
A Phoenix transmitter
A flashlight with a NVG compatible filter
A tree trunk silhouetted against the night sky
A piece of white paper

5. Set the objective lens focus --- focus the goggles for the object's distance. [The objective lens focus is the outside lens located at the end of the NVG image intensification tube. It adjusts for distance only. When the objective lens focus is turned to its full left or counterclockwise position, it is on the maximum distance or infinity setting. Use this setting, when looking at objects farther than 30 ft from you.]

→ Turn the objective lens focus to the right or to the left until the object you are looking at is as clear as possible.

→ If the object you are viewing is beyond 30 ft, simply turn the objective lens focus to its full left or counterclockwise position.

6. Set the diopter adjustment ring for each eye to adjust for the unique vision in each of your eyes. [The diopter adjustment rings are the two rings closest to your eyes. These rings can be rotated to correct for refractive errors in your eyes (that is, whether you are near-sighted or far sighted), and will determine the visual acuity you can obtain with the illumination available.]

→ First, close one eye and adjust the diopter ring for the open eye.

→ Turn the diopter adjustment ring to the left (counterclockwise) until it stops.

→ Stop for a second, blink, and let your open eye relax.

→ Slowly turn the diopter adjustment ring back to the right (clockwise) until the object just becomes sharp. **Stop!!** Do not turn the diopter ring beyond this point. Do not go beyond the initial clear focus.

If you are adjusting to a light source, when you turn the diopter adjustment ring to the right (clockwise), stop at the point where the bloom is minimized. If the light source has a double bloom, that is, a center point of light and a larger surrounding bloom, turn the diopter adjustment ring until the center light source is as small as possible and the image is circular.

→ Repeat these procedures for the other eye.

7. Check the objective lens focus again (Step #5).

This will ensure your distance focus is still sharp. Readjust if necessary.

8. Repeat steps 6 and 7 as necessary to determine if you have the best adjustment.

Reminders:

→ Do not readjust the diopter adjustment rings once good visual acuity has been achieved.

→ You must readjust the objective lens focus to correspond to the distance of objects you encounter in the field to provide the sharpest image.

→ Optimum visual acuity (sharpness of vision) with night vision goggles occurs with good illumination at night and when you use a high-contrast object to make your diopter adjustments. Visual acuity becomes worse under very low light level conditions and when you use a low-contrast object.